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ABSTRACT

Metacognitive skills may be defined in a variety of ways. Generally, these ways all apply to people's thinking about their own personal thinking. This research study analyzed students' interactions to computer programs to assess their metacognitive skills. The metacognitive skills assessed were: (1) planning a course of action; (2) monitoring the outcomes; (3) evaluating data collection strategies; (4) thinking about or listing alternative strategies; (5) revising strategies; and (6) prioritizing actions. The participants were observed individually or in pairs during their work on specific programs. The participants were observed during each interaction and a record was kept of their verbal behavior and of their computer responses. Overall, subjects varied widely in their ability to choose a course of action. The subjects sometimes would sit and appear to consider what to do before they attempted the problem. Subjects were more capable of monitoring the outcomes of their decisions when they had had some positive experiences with this strategy. Revising strategies was most difficult. The subjects were not able to prioritize their actions. (KR)

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AN ANALYSIS OF METACOGNITIVE SKILLS UTILIZED BY STUDENTS DURING COMPUTER SIMULATION ACTIVITIES

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Introduction

One of the most important functions of the human mind is the ability to observe itself. This ability has led many educators to study the phenomena of metacognition during science activities. The phenomena of metacognition is for all practical purposes not possible with the computers we presently use in our middle school, junior high school, or senior high school classrooms. For the most part acts similar to metacognition are a part of computer science known as artificial intelligence. In this sub-discipline attempts are made to develop programs capable of playing master level chess, interpreting pictures, or interpreting natural language and other things. While classroom computers often do not do this, they may be used with verbal feedback, comments, and keystroke analysis to assess and analyze metacognitive processes in students. This means that the students themselves must engage in metacognitive activities. That is, the strategies which children employ to solve novel problems may be stored, compared, and analyzed. These strategies then reveal some of the underlying thinking processes of students.

Conceptual Framework

Metacognitive skills may be defined in a variety of ways. Generally, these ways all apply to a person's thinking about their own personal thinking. Some of the specific skills include:

(1) Planning a course of action

(2) Monitoring the outcomes

(3) Evaluating data collection strategies

(4) Thinking about or listing alternative actions

(5) Revising strategies

(6) Prioritizing actions

These skills are those that are involved in choosing, planning, and evaluating what is being done (Garofalo and Lester, 1985). Science education researchers (Berger, 1982: Kantowski, 1977: Linn, 1987: Schoenfeld, 1982) have studied various aspects of teaching utilizing computer programs. These studies have shown overall that subjects do use different kinds and amounts of metacognitive thinking during interactions with computers. Additionally these studies have illustrated that current researchers in the area of computers in science education need to be considering metacognitive skills of students. In additional studies conducted (Thomas and Grouws, 1984) it has been found that focusing on specific aspects of metacognition,

developing an awareness of and a concern for respective metacognitive processes and monitoring results has benefited subjects in their problem solving tasks. Subjects have often used both reflective and anticipatory thinking while doing problem solving tasks. A study done by Adams and Shrum (1990) revealed that level of cognitive development was not related to achievement in a microcomputer-based laboratory exercise in biology. Similarly a study done by Flick (1990) revealed that students were not affected by the gamelike features of computer simulations.

Research Questions and Procedures

This research made use of microcomputer simulation and game situations to study student's metacognitive skills during computer enhanced activities. It expanded the research previously reported by Horak (1990) in that it utilized different computer programs and different coding schemes. The computer programs employed were (1) Magic Mirrors, (2) Funny Numbers, and (3) Animals. The first program requires subjects to find the position and angle of mirrors placed in a four by four grid. This is done by "shooting" light beams into the grid and finding the position they exit the grid. By recording data they can infer the correct placement of the mirrors in the original grid. The second program involves the subjects by having them find special fractional numbers which may be reduced by alternative algorithms to yield correct fractions. An

example of this is 16/64 which may be reduced correctly by crossing out the 6 in the ones place in the numerator with the 6 in the denominator. Subjects are challenged to determine other examples of numbers where cancellation properties of this sort may apply. The third program involves a simulation where subjects try to feed animals by throwing food over a barrier into their pen. The subjects must infer which angles of throw and what velocity of throw will result in the food entering the pen. The determination is possible by recording the data and methodically revising angles and velocities. This program is made more difficult by the fact that students may use the same angle or velocity only a finite number of times.

Through observing subjects interactions with these programs it was possible to address the following questions:

(1) What are the initial procedures used by subjects to initially solve the explained problem?

(2) Do subjects monitor their results to change their strategies as the program progresses?

(3) Do subjects choose differing metacognitive strategies based upon the characteristics of the computer program or upon their recorded actions?

(4) Is a change in metacognitive strategy influenced by prior success or failure at a computer simulation task?

To investigate these questions, the participants were observed as they worked individually or in pairs at the

computer. During each interaction a record was kept of their verbal behavior and of their computer responses. The data collected was analyzed by science and mathematics educators utilizing an interaction grid which identified the relevant metacognitive processes. The subjects analyzed spent an average of forty to fifty minutes trying to solve the presented problems. Some subjects were able to attempt more than one computer program during this time. Others did not finish any of the required activities. There was no time limit set for the activities, but subjects were allowed to interact with the computer as long as they desired.

Findings and Conclusions

The analysis of the records revealed the following general observations and consistencies in the use of metacognitive processes and skills during interaction with the preceding computer programs.

(1) Overall, subjects vary widely in their ability to choose a course of action. The subjects sometimes would sit and appear to consider what to do before they attempted the problem. That is, after reading the directions, some subjects started immediately to interact with the computer program and others sat and re-read the directions or tried to decide what was the best strategy for solution. This did not appear to be connected to the ability or the age of the subjects.

(2) Subjects are more capable of monitoring the outcomes of their decisions when they have some positive experience with this strategy. Subjects who were successful on a prior task were more willing to think about their actions.

(3) Revising strategies was most difficult. subjects who were successful with one strategy in an initial problem were more inclined to pursue that strategy in a different situation whether or not it yielded useful results.

(4) The subjects were not able to prioritize their actions. They chose their initial and many subsequent lines of action based upon incorrect inferences made from the accumulated data.

This research is exploratory in that it was designed to build a foundation for the analysis of qualitative and quantitative data on metacognitive processes and skills used during computer assisted instruction. The programs utilized were simple enough to allow subjects to choose alternative solution procedures based upon their metacognitive processes. The information gained from this study will aid in focusing future research in the utilization of computer programs in science education. It may also lead to the development of computer software that requires subjects to monitor and/or change their current cognitive processes.

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